[4910-13]

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Parts 23, 25 and 33

[Docket No. 28652; Amendment Nos. 23-53, 25-95, and 33-19]

RIN 2120-AF75

Airworthiness Standards; Rain and Hail Ingestion Standards

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Final rule.

SUMMARY: These amendments establish revisions to the Federal Aviation Administration's certification standards for rain and hail ingestion for aircraft turbine engines. These amendments address engine power-loss and instability phenomena attributed to operation in extreme rain or hail that are not adequately addressed by current requirements. These amendments also generally harmonize these standards with rain and hail ingestion standards being amended by the Joint Aviation Authorities (JAA). These amendments establish nearly uniform standards for engines certified in the United States under 14 CFR part 33 and in the JAA countries under Joint Airworthiness Requirements-Engines (JAR-E), thereby simplifying the certification of engine designs by the FAA and the JAA.

EFFECTIVE DATE: April 30, 1998

FOR FURTHER INFORMATION CONTACT: John Fisher, Engine and Propeller Standards Staff, ANE-110, Engine and Propeller Directorate, Aircraft Certification Service, FAA, New England Region, 12 New England Executive Park, Burlington, Massachusetts 01803-5229; telephone (781) 238-7149; fax (781) 238-7199.

SUPPLEMENTARY INFORMATION

Availability of Final Rules

An electronic copy of this document may be downloaded, using a modem and suitable communications software, from the FAA regulations section of the Fedworld electronic bulletin board service (telephone: 703-321-3339), the **Federal Register's** electronic bulletin board service (2002-512-1661), or the FAA's Aviation Rulemaking Advisory Committee Bulletin Board service (telephone 202-267-5948).

Internet users may reach the FAA's web page at http://www.faa.gov or the **Federal Register's** web page at http://www.access.gpo.gov/su_ docs for access to recently published rulemaking documents.

Any person may obtain a copy of this final rule by submitting a request to the Federal Aviation Administration, Office of Rulemaking, ARM-1, 800 Independence Avenue, SW., Washington, DC 20591, or by calling (202) 267-9680. Communications must identify the amendment number or document number of this final rule.

Persons interested in being placed on the mailing list for future notices of proposed rulemaking and final rulemaking should request from the above office a copy of Advisory Circular No. 11-2A, Notices of Proposed Rulemaking Distribution System, that describes the application procedure.

Small Entity Inquiries

The Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA) requires the FAA to report inquiries from small entities concerning information on, and advice about, compliance with statutes and regulations within the FAA's jurisdiction, including interpretation and application of the law to specific sets of facts supplied by a small entity.

If you are a small entity and have a question, contact your local FAA official. If you do not know how to contact your local FAA official, you may contact Charlene Brown, Program Analyst Staff, Office of Rulemaking, ARM-27, Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, 1-888-551-1594. Internet users can find additional information on SBREFA in the "Quick Jump" section of the FAA's web page at http://www.faa.gov and may send electronic inquiries to the following internet address: 9-AWA-SBEFA@faa.dot.gov.

Background

Statement of the Problem

There have been a number of multiple turbine engine power-loss and instability events, forced landings, and accidents attributed to operating airplanes in extreme rain or hail. Investigations have revealed that ambient rain or hail concentrations can be amplified significantly through the turbine engine core at high flight speeds and low engine power conditions. Rain or hail through the turbine engine core may degrade compressor stability, combustor flameout margin, and fuel control run down margin. Ingestion of extreme quantities of rain or hail through the engine core may ultimately produce a number of engine anomalies, including surging, power loss, and engine flameout.

Industry Study

In 1987, the Aerospace Industries Association (AIA) initiated a study of natural icing effects on high bypass ratio (HBR) turbofan engines that concentrated primarily on the mechanical damage aspects of icing encounters. It was discovered during that study that separate power-loss and instability phenomena existed that were not related to mechanical damage. Consequently, in 1988 another AIA study was initiated to determine the magnitude of these threats and to recommend changes to part 33, if appropriate. AIA,

working with the Association Europeenne des Constructeurs de Materiel Aerospatial (AECMA), concluded that a potential flight safety threat exists for turbine engines installed on airplanes operating in extreme rain and hail. Further, the study concluded that the current water and hail ingestion standards of 14 CFR part 33 do not adequately address this threat.

Engine Harmonization Effort

The FAA is committed to undertaking and supporting harmonization of standards in part 33 with those in Joint Aviation Requirements-Engines (JAR-E). In August 1989, as a result of that commitment, the FAA Engine and Propeller Directorate participated in a meeting with the Joint Aviation Authorities (JAA), AIA, and AECMA. The purpose of the meeting was to establish a philosophy, guidelines, and a working relationship regarding the resolution of issues arising from standards that need harmonization, including the adoption of new standards when needed. All parties agreed to work in partnership to address jointly the harmonization task. This partnership was later expanded to include the airworthiness authority of Canada, Transport Canada.

This partnership identified seven items which were considered the most critical to the initial harmonization effort. New rain and hail ingestion standards are an item on this list of seven items and, therefore, represent a critical harmonization effort.

Aviation Rulemaking Advisory Committee Project

In December 1992, the FAA requested the Aviation Rulemaking Advisory Committee (ARAC) to evaluate the need for new rain and hail ingestion standards. This task, in turn, was assigned to the Engine Harmonization Working Group (EHWG) of the Transport Airplane and Engine Issues Group (TAEIG) on December 11, 1992 (57 FR 58840). On November 7, 1995, the TAEIG recommended to the FAA that it proceed

with rulemaking and associated advisory material even though one manufacturer expressed reservations. The FAA published a notice of proposed rulemaking on August 9, 1996 (61 FR 41688). This rule and associated advisory material reflect the ARAC recommendations.

Discussion of Comments

All interested persons have been afforded an opportunity to participate in this rulemaking, and due consideration has been given to all comments received. The commenters represent domestic and foreign industry, and foreign airworthiness authorities. Five commenters provided the FAA with comments to the NPRM.

Four commenters expressed concern with the proposed wording for §§ 23.903 and 25.903. The commenters state that the proposal could result in retroactive requirements imposed on certain engines already type certificated. Three of the four commenters further state that this part of the proposal represents a significant departure from the proposal submitted to the FAA by ARAC.

The FAA agrees. It was not the intent of the FAA to retroactively impose the new requirements on an engine design already type certificated unless service history indicates that an unsafe condition is present. The FAA has changed the wording for §§ 23.903 and 25.903 back to that originally proposed by the ARAC .

All five commenters found a number of typographical errors and suggested some editorial changes. One notable typographical error appeared in the "Disposition of Comments" section of the preamble of the proposal. When addressing a concern that the hail threat definition was apparently rounded up to 10 g/m^3 , the value 8/3 g/m^3 was incorrect and should have been written as 8.7 g/m^3.

The FAA also agrees to the other recommendations by the commenters and the following grammatical corrections and changes to § 33.78 and Appendix B have been made to this rule:

Section 33.78(a)(1): "Critical inlet fact area" has been changed to "Critical inlet face area" and the last sentence revised to read, "The hailstones shall be ingested in a rapid sequence to simulate a hailstone encounter and the number and size of the hailstones shall be determined as follows:".

Section 33.78(a)(1)(ii): The term "one 20-inch" has been changed to "one 2-inch".

Section 33.78(a)(2): The following has been added to the beginning of the paragraph, "In addition to complying with paragraph (a)(1) of this section and", and a comma has been added immediately following the phrase "or loss of acceleration and deceleration capability".

Section 33.78(b)(4): "deceleration" has been replaced with "acceleration".

Appendix B, Table B3: "Contribution to total LWC (%)" has been changed to "Contribution to total RWC (%)".

Appendix B, Table B4: The term "0.4.9" has been changed to "0-4.9", and "hailstone" has been replaced with "hail" in the title, column heading, and footnote.

One commenter provided an additional clarifying statement with respect to the hail threat level variations obtained from the Industry Study. Given an extremely remote encounter probability and a typical thirty second exposure to severe hail, the assessed hail threat level varies from 8.7 g/m^3 to 10.2 g/m^3, depending upon the airspeed of the aircraft traversing the hail shaft.

The FAA agrees with the commenter's additional explanation of the assessed hail threat variation. However, the discussion of the Industry Study in the proposal is technically correct.

One commenter states the need for advisory material to accompany the rule to clarify various terms and criteria contained in the rule.

The FAA agrees. An extensive advisory circular (AC) was drafted providing explanation of the various terms and criteria contained in the rule. The FAA issued a notice of availability of proposed AC and request for comments on September 5, 1996 (61 FR 46893). Further information regarding this AC can be obtained by contacting the FAA at the address specified under "FOR FURTHER INFORMATION CONTACT:".

One commenter suggested changes to the preamble discussion regarding power loss and performance degradation. The commenter did not suggest nor imply that any changes to the proposed rule were needed. The FAA need not address those comments since they do not affect the meaning of these regulations.

One commenter states that the criterion of no flameout contained in § 33.78(a)(2) and § 33.78(b) was excessive. The commenter further states that many engines are equipped with automatic re-ignition systems that would ensure quick recovery from a flameout.

The FAA disagrees. Automatic re-ignition systems can facilitate quick recovery from a flameout as a result of a momentary ingestion, such as an ice shed. However, the rain and hail ingestion threats addressed by the new standards are not momentary, and have been defined for purposes of certification testing as 30 seconds duration for hail and 3 minutes duration for rain. Once flameout occurs under these conditions, it is unlikely that the engine will be capable of recovery until the ingestion of rain or hail ceases, with or

without an automatic re-ignition system. Also, for actual encounters of severe rain and hail, it is likely that the engine will continue to ingest water, at lower concentrations, after exiting the area of severe rain or hail. The effect of this ingested water is to lower the starting capability of the engine. Therefore, if an airplane encounters severe rain or hail with installed engines that are susceptible to flameout, the airplane will be susceptible to an all engine out, forced landing. For these reasons, demonstrating tolerance to flameout under conditions of extreme rain and hail is a primary objective of the new standards.

One commenter states that the acceptance criteria for rain and hail ingestion contained in § 33.78(a)(2) and § 33.78(b) appeared to be more stringent than the acceptance for ice ingestion. The commenter believes that the acceptance criteria for rain and hail ingestion should be less stringent than for ice ingestion, since ice ingestion is a more common occurrence than hail ingestion.

The FAA concurs with the commenter that the stringency of acceptance criteria should be proportional to the occurrence rate of the threat being assessed. However, the FAA disagrees with the commenter's view that the acceptance criteria for rain and hail ingestion are more stringent than for ice ingestion. Some amount of sustained power or thrust loss is permitted following testing to the new rain and hail ingestion standards, but no power or thrust loss is permitted following an ice ingestion test. Also, the FAA would accept momentary but recoverable surges and stalls encountered while testing to the new rain and hail ingestion standards, but has not historically accepted momentary surges and stalls following an ice ingestion test. Flameout, run down, continued or non-recoverable surge or stall, and loss of acceleration and deceleration are unacceptable conditions for rain, hail and ice ingestion.

Finally, the FAA has made the following minor editorial changes to better align this rule with recent changes to the JAA's requirements. These changes do not affect the scope of the rule or change the intent of these sections.

Section 33.78(a)(1): The phrase "maximum true air speed" replaces the phrase "maximum rough air speed", and the phrase "operating in rough air" is added following the words "representative aircraft".

Section 33.78(a)(1)(i) and (ii): The word "area" is changed to read "areas".

Section 33.78(c): In the first sentence the phrase "complying with paragraph (a)(1) of this section" is changed to read "complying with paragraphs (a)(1) and (a)(2) of this section.

Appendix B: The word "hailstones" is changed to read "hail" in the introductory paragraph and also in Table B4.

After careful review of all the comments, the FAA has determined that air safety and the public interest require the adoption of the rule with the changes described.

Paperwork Reduction Act

In accordance with the Paperwork Reduction Act of 1995 (44 U.S.C. 3507(d), there are no information collection requirements associated with this final rule.

Regulatory Evaluation Summary

Proposed changes to Federal regulations must undergo several economic analyses. First, Executive Order 12866 directs that each Federal agency shall propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs. Second, the Regulatory Flexibility Act of 1980 requires agencies to analyze the economic effect of regulatory changes on small entities. Third, the Office of Management and Budget directs agencies to

assess the effects of regulatory changes on international trade. In conducting these analyses, the FAA has determined that this rule: (1) will generate benefits that justify its costs and is not a "significant regulatory action" as defined in the Executive Order; (2) is not significant as defined in DOT's Regulatory Policies and Procedures; (3) will not have a significant impact on a substantial number of small entities; and (4) will not constitute a barrier to international trade. These analyses, available in the docket, are summarized below.

Incremental costs

The proposed rule will permit a range of compliance options, thereby enabling manufacturers to select cost-minimizing approaches. Approaches that maximize the use of analytical methods will most likely be the least expensive means to demonstrate compliance, while approaches that rely primarily on engine testing in a simulated rain and hail environment will likely be the most costly. Incremental certification cost estimates supplied by industry varied depending on engine model and the testing method used.

FAA conservatively estimates that incremental certification costs for an airplane turbine engine design will be approximately $627,000-- this includes $300,000 in additional engineering hours, and $327,000 for the prorated share of the cost of a test facility.

Based on statements from industry, the FAA expects that, once Rain/Hail centrifuging and engine cycle models are established, compliance will be accomplished through design modifications that will have little impact on manufacturing costs. Such design features may affect: 1) fan blade/propeller, 2) spinner/nose cone, 3) bypass splitter, 4) engine bleeds, 5) accessory loads, 6)

variable stator scheduling, and 7) fuel control. Similarly, the FAA expects that the rule will have a negligible effect on operating costs.

Expected Benefits

Rain or hail related in-flight engine shutdowns are rare occurrences. This is due, in large part, to the high quality of meteorological data available to ground controllers and pilots, and to well established weather avoidance procedures. However, while such events are infrequent, they pose a serious hazard because they typically occur during a critical phase of flight where recovery is difficult or impossible.

An examination of the FAA accident/incident database system and National Transportation Safety Board (NTSB) records revealed two accidents that were the result of inflight engine shutdowns or rundowns caused by excessive water ingestion. In each case, the aircraft was in the descent phase of flight. These accidents form the basis of the expected benefits of the subject rule. However, what follows should be considered a conservative estimate of the rule's potential benefits for three reasons.

First, the rule should have the effect of increasing turbine engine water ingestion tolerance regardless of the source of water. Accident/incident records show that many events (not included in the benefit estimates that follow) were caused by other forms of water such as snow and graupel. It is possible that some of these cases would have benefited from the subject rule.

Second, several other incidents, while not resulting in a crash, nevertheless had catastrophic potential. This potential could be exacerbated by the development of more efficient turbofan powerplants which have permitted large

aircraft designs incorporating fewer engines. An industry study identified seven events (not recorded in either the FAA or NTSB databases) in which rain and/or hail affected two or more engines and resulted in an inflight shutdown of at least one engine.

Third, heavy rain and hail are often accompanied by severe turbulence and windshear. While recovery from a water induced engine shutdown is frequently successful, the ability to maintain engine power during an encounter with an unexpected downdraft could be crucial to avoiding a crash.

The available accident and aircraft usage data suggest the categories that are used to classify the benefits of the subject rule. These classifications are: 1) large air carrier aircraft (operated by major and national air carriers), and 2) other air carrier aircraft (operated by large regional, medium regional, commuter, and other small certificated air carriers). An examination of accident records for the 20-year period 1975-1994 indicates that, in the absence of the subject rule, the probability of a hull loss due to a water induced loss of engine power is 0.0094 per million departures for large air carriers, and 0.0249 per million departures for other air carriers.

The calculation of the rule's benefits, then, depends on the degree to which the rule can reduce this risk. According to industry representatives, compliance with the revised water ingestion standards will reduce the rate of engine power loss events by two orders of magnitude. This analysis assumes that the rule’s effect on the accident rate will be proportionately equal to the rule’s effect on the event rate.

Using projections from the FAA Aviation Forecast, this analysis assumes that the average large air carrier airplane has 168 seats and a load factor of 61%. The average regional air carrier airplane is assumed to have 30 seats and a load factor of 51%. The estimated distribution of fatal, serious, and minor injuries is based on the actual distribution of casualties in the accidents cited above. On the basis of these assumptions, FAA estimates the annual benefits of prevented casualties per airplane will be $3,360 for large air carriers and $618 for other air carriers.

Benefits and Costs Analysis

The benefits and costs of the rule are compared for two representative engine certifications: 1) An engine designed for operation on a large jet transport (corresponding to the "large air carrier" category described earlier), and 2) an engine designed for operation on a regional transport (corresponding to the "other air carrier" category).

For each certification, the following assumptions apply: 1) 50 engines are produced per year for 10 years (500 total engines produced per certification), 2) incremental certification costs are incurred in the year 2000, 3) engine production begins in the year 2002, 4) the first engines enter service in the year 2003, 5) each engine is retired after 10 years, 6) the discount rate is 7%. Also, in order to compare incremental engine costs with expected benefits (which are expressed in terms of the reduction in the aircraft accident rate) this analysis assumes that each aircraft has two engines.

Under the assumptions enumerated above, total lifecycle benefits for a representative engine designed for operation on a large airplane equal

approximately $9.3 million or $3.5 million at present value (1997 dollars). Total lifecycle benefits for a representative engine designed for operation on a regional airplane equal to approximately $1.8 million or $0.7 million at present value.

This analysis postulates that incremental certification costs for both representative engine designs are the same. As discussed above, incremental costs are approximately $627,000 or $512,000 at present value.

FAA finds that the rule would be cost-beneficial. Under very conservative production, service life, and incremental engine certification cost assumptions, the expected discounted benefits of prevented casualties and aircraft damage will exceed costs by a ratio ranging from 6.9 to 1 for large air carriers to 1.3 to 1 for other air carriers.

Harmonization Benefits

In addition to the benefits of increased safety, the rule harmonizes with JAR requirements, thus reducing costs associated with certificating aircraft turbine engines to differing airworthiness standards.

Regulatory Flexibility Determination

The Regulatory Flexibility Act of 1980 establishes "as a principle of regulatory issuance that agencies shall endeavor, consistent with the objectives of the rule and of applicable statutes, to fit regulatory and informational requirements to the scale of the businesses, organizations, and governmental jurisdictions subject to regulation." To achieve that principle, the Act requires agencies to solicit and consider flexible regulatory proposals and to explain the rationale for their actions. The Act covers a wide range of small entities, including small businesses, not-for-profit organizations and small governmental jurisdictions.

Agencies must perform an analysis to determine whether a rule will have a significant economic impact on a substantial number of small entities; if the determination is that it will, the agency must prepare a regulatory flexibility analysis (RFA).

However, if after an analysis for a proposed or final rule, an agency determines that a rule is not expected to have a significant economic impact on a substantial number of small entities, § 605(b) of the 1980 act provides that the head of the agency may so certify. The certification must include a statement providing the factual basis for this determination, and the reasoning should be clear.

The FAA conducted the required preliminary analysis of this proposal and determined that it would not have a significant economic impact on a substantial number of small entities. That determination was published in the Federal Register on August 9, 1996 as part of the Notice of Proposed Rulemaking. No comments were received regarding the economic analysis of the rule. No substantial changes were made in the final rule from the proposed rule, and estimated costs were not significantly modified. Accordingly, pursuant to the Regulatory Flexibility Act, 5 U.S.C. § 605(b), the Federal Aviation Administration certifies that this rule will not have a significant economic impact on a substantial number of small entities.

International Trade Impact Assessment

The rule will have little or no effect on trade for either U.S. firms marketing turbine engines in foreign markets or foreign firms marketing turbine

engines in the U.S. Generally, this rule harmonizes FAA requirements with existing and proposed JAA requirements.

Federalism Implication

The regulations will not have substantial direct effects on the states, on the relationship between the national government and the states, or on the distribution of power and responsibilities among the various levels of government. Therefore, in accordance with Executive Order 12612, it is determined that this rule will not have sufficient federalism implications to warrant the preparation of a Federalism Assessment.

Unfunded Mandates Reform Act

Title II of the Unfunded Mandates Reform Act of 1995 (The Act), enacted as Pub. L. 104-4 on March 22, 1995, requires each federal agency, to the extent permitted by law, to prepare a written assessment of the effects of any federal mandate in a proposed or final agency rule that may result in the expenditure by state, local, and tribal governments, in the aggregate, or by the private sector, of $100 million or more (adjusted annually for inflation) in any one year. Section 204(A) of The Act, 2 U.S.C. 1534(A), requires the federal agency to develop an effective process to permit timely input by elected officers (or their designees) of state, local, and tribal governments on a proposed "significant intergovernmental mandate". A "significant intergovernmental mandate" under The Act is any provision in a federal agency regulation that will impose an enforceable duty upon state, local, and tribal governments, in the aggregate, of $100 million (adjusted annually for inflation) in any one year. Section 203 of The Act, 2 U.S.C. 1533, which supplements section 204(A), provides that before establishing any regulatory requirements that might significantly or uniquely affect small governments, the agency shall have developed a plan

that, among other things, provides for notice to potentially affected small governments, if any, and for a meaningful and timely opportunity to provide input in the development of regulatory proposals**.**

The FAA determines that this rule does not contain a significant intergovernmental or private sector mandate as defined by the act.

List of Subjects in 14 CFR Parts 23, 25 and 33

Air transportation, Aircraft, Aviation safety, Safety.

Adoption of the Amendments

In consideration of the foregoing, the Federal Aviation Administration amends 14 CFR parts 23, 25, and 33 as follows:

PART 23 - AIRWORTHINESS STANDARDS: NORMAL, UTILITY, ACROBATIC, AND COMMUTER CATEGORY AIRPLANES

1. The authority citation for part 23 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701-44702, 44704.

2. Section 23.901 is amended by revising paragraph (d)(2) to read as follows:

§ 23.901 Installation.

***** ***** ***** ***** *****

(d) * * *

(2) Ensure that the capability of the installed engine to withstand the ingestion of rain, hail, ice, and birds into the engine inlet is not less than the capability established for the engine itself under § 23.903(a)(2).

* * * * *

3. Section 23.903 is amended by revising paragraph (a)(2) to read as follows:

§ 23.903 Engines.

(a) * * *

(2) Each turbine engine must either-

(i) Comply with § 33.77 and § 33.78 of this chapter in effect on April 30, 1998; or as subsequently amended; or

(ii) Comply with § 33.77 of this chapter in effect on October 31, 1974, or as subsequently amended prior to April 30, 1998, and must have a foreign object ingestion service history that has not resulted in any unsafe condition; or

(iii) Be shown to have a foreign object ingestion service history in similar installation locations which has not resulted in any unsafe condition.

Note: § 33.77 of this chapter in effect on October 31, 1974, was published in 14 CFR parts 1 to 59, Revised as of January 1, 1975. See 39 FR 35467, October 1, 1974.

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PART 25 - AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

4. The authority citation for part 25 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701-44702, 44704.

5. Section 25.903 is amended by revising paragraph (a)(2) to read as follows:

§ 25.903 Engines.

(a) * * *

(2) Each turbine engine must either-

(i) Comply with § 33.77 and § 33.78 of this chapter in effect on April 30, 1998; or as subsequently amended; or

(ii) Comply with § 33.77 of this chapter in effect on October 31, 1974, or as subsequently amended prior to April 30, 1998, and must have a foreign object ingestion service history that has not resulted in any unsafe condition; or

(iii) Be shown to have a foreign object ingestion service history in similar installation locations which has not resulted in any unsafe condition.

Note: § 33.77 of this chapter in effect on October 31, 1974, was published in 14 CFR parts 1 to 59, Revised as of January 1, 1975. See 39 FR 35467, October 1, 1974.

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PART 33 - AIRWORTHINESS STANDARDS: AIRCRAFT ENGINES

6. The authority citation for part 33 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701-44702, 44704.

7. Section 33.77 is amended by revising paragraphs (c) and (e) to read as follows:

§ 33.77 Foreign object ingestion.

* * * * *

(c) Ingestion of ice under the conditions prescribed in paragraph (e) of this section, may not cause a sustained power or thrust loss or require the engine to be shut down.

* * * * *

(e) Compliance with paragraphs (a), (b), and (c) of this section must be shown by engine test under the following ingestion conditions:

FOREIGN OBJECT	TEST QUANTITY	SPEED OF FOREIGN OBJECT	ENGINE OPERATION	INGESTION
BIRDS:				
3-Ounce size	One for each 50 square inches of inlet area, or fraction thereof, up to a maximum of 16 birds. Three-ounce bird ingestion not required if a 1-1/2-pound bird will pass the inlet guide vanes into the rotor blades.	Liftoff speed of typical aircraft.	Takeoff	In rapid sequence to simulate a flock encounter and aimed at selected critical areas.
1-1/2-pound size	One for the first 300 square inches of inlet area, if it can enter the inlet, plus one for each additional 600 square inches of inlet area, or fraction, thereof up to a maximum of 8 birds.	Initial climb speed of typical aircraft.	Takeoff	In rapid sequence to simulate a flock encounter and aimed at selected critical areas.
4-pound size	One, if it can enter the inlet.	Maximum climb speed of typical aircraft, if the engine has inlet guide vanes. Liftoff speed of typical aircraft, if the engine does not have inlet guide vanes.	Maximum cruise Takeoff	Aimed at critical area. Aimed at critical area.
ICE :				
Maximum accumulation on a typical inlet cowl and engine face resulting from a 2-minute delay in actuating anti-icing system, or a slab of ice which is comparable in weight or thickness for that size engine.	Sucked in.		Maximum cruise	To simulate a continuous maximum icing encounter at 25ºF.

Note: The term "inlet area" as used in this section means the engine inlet projected area at the front face of the engine. It includes the projected area of any spinner or bullet nose that is provided.

8. Section 33.78 is added to part 33, to read as follows:

§ 33.78 Rain and hail ingestion.

(a) All engines.

(1) The ingestion of large hailstones (0.8 to 0.9 specific gravity) at the maximum true air speed, up to 15,000 feet (4,500 meters), associated with a representative aircraft operating in rough air, with the engine at maximum continuous power, may not cause unacceptable mechanical damage or unacceptable power or thrust loss after the ingestion, or require the engine to be shut down. One-half the number of hailstones shall be aimed randomly over the inlet face area and the other half aimed at the critical inlet face area. The hailstones shall be ingested in a rapid sequence to simulate a hailstone encounter and the number and size of the hailstones shall be determined as follows:

(i) One 1-inch (25 millimeters) diameter hailstone for engines with inlet areas of not more than 100 square inches (0.0645 square meters).

(ii) One 1-inch (25 millimeters) diameter and one 2-inch (50 millimeters) diameter hailstone for each 150 square inches (0.0968 square meters) of inlet area, or fraction thereof, for engines with inlet areas of more than 100 square inches (0.0645 square meters).

(2) In addition to complying with paragraph (a)(1) of this section and except as provided in paragraph (b) of this section, it must be shown that each engine is capable of acceptable operation throughout its specified operating envelope when subjected to sudden encounters with the certification standard concentrations of rain and hail, as defined in Appendix B to this part. Acceptable engine operation precludes flameout, run down, continued or non-recoverable surge or stall, or loss of acceleration and deceleration capability, during any three minute continuous period in rain and during any 30 second

continuous period in hail. It must also be shown after the ingestion that there is no unacceptable mechanical damage, unacceptable power or thrust loss, or other adverse engine anomalies.

(b) Engines for rotorcraft. As an alternative to the requirements specified in paragraph (a)(2) of this section, for rotorcraft turbine engines only, it must be shown that each engine is capable of acceptable operation during and after the ingestion of rain with an overall ratio of water droplet flow to airflow, by weight, with a uniform distribution at the inlet plane, of at least four percent. Acceptable engine operation precludes flameout, run down, continued or non-recoverable surge or stall, or loss of acceleration and deceleration capability. It must also be shown after the ingestion that there is no unacceptable mechanical damage, unacceptable power loss, or other adverse engine anomalies. The rain ingestion must occur under the following static ground level conditions:

(1) A normal stabilization period at take-off power without rain ingestion, followed immediately by the suddenly commencing ingestion of rain for three minutes at takeoff power, then

(2) Continuation of the rain ingestion during subsequent rapid deceleration to minimum idle, then

(3) Continuation of the rain ingestion during three minutes at minimum idle power to be certified for flight operation, then

(4) Continuation of the rain ingestion during subsequent rapid acceleration to takeoff power.

(c) Engines for supersonic airplanes. In addition to complying with paragraphs (a)(1) and (a)(2) of this section, a separate test for supersonic airplane engines only, shall

be conducted with three hailstones ingested at supersonic cruise velocity. These hailstones shall be aimed at the engine's critical face area, and their ingestion must not cause unacceptable mechanical damage or unacceptable power or thrust loss after the ingestion or require the engine to be shut down. The size of these hailstones shall be determined from the linear variation in diameter from 1-inch (25 millimeters) at 35,000 feet (10,500 meters) to 1/4-inch (6 millimeters) at 60,000 feet (18,000 meters) using the diameter corresponding to the lowest expected supersonic cruise altitude. Alternatively, three larger hailstones may be ingested at subsonic velocities such that the kinetic energy of these larger hailstones is equivalent to the applicable supersonic ingestion conditions.

(d) For an engine that incorporates or requires the use of a protection device, demonstration of the rain and hail ingestion capabilities of the engine, as required in paragraphs (a), (b), and (c) of this section, may be waived wholly or in part by the Administrator if the applicant shows that:

(1) The subject rain and hail constituents are of a size that will not pass through the protection device;

(2) The protection device will withstand the impact of the subject rain and hail constituents; and

(3) The subject of rain and hail constituents, stopped by the protection device, will not obstruct the flow of induction air into the engine, resulting in damage, power or thrust loss, or other adverse engine anomalies in excess of what would be accepted in paragraphs (a), (b), and (c) of this section.

9. Appendix B is added to part 33, to read as follows:

APPENDIX B TO PART 33--CERTIFICATION STANDARD ATMOSPHERIC CONCENTRATIONS OF RAIN AND HAIL

Figure B1, Table B1, Table B2, Table B3, and Table B4 specify the atmospheric concentrations and size distributions of rain and hail for establishing certification, in accordance with the requirements of § 33.78(a)(2). In conducting tests, normally by spraying liquid water to simulate rain conditions and by delivering hail fabricated from ice to simulate hail conditions, the use of water droplets and hail having shapes, sizes and distributions of sizes other than those defined in this Appendix B, or the use of a single size or shape for each water droplet or hail, can be accepted, provided the applicant shows that the substitution does not reduce the severity of the test.

FIGURE B1 - Illustration of Rain and Hail Threats. Certification concentrations are obtained using Tables B1 and B2.

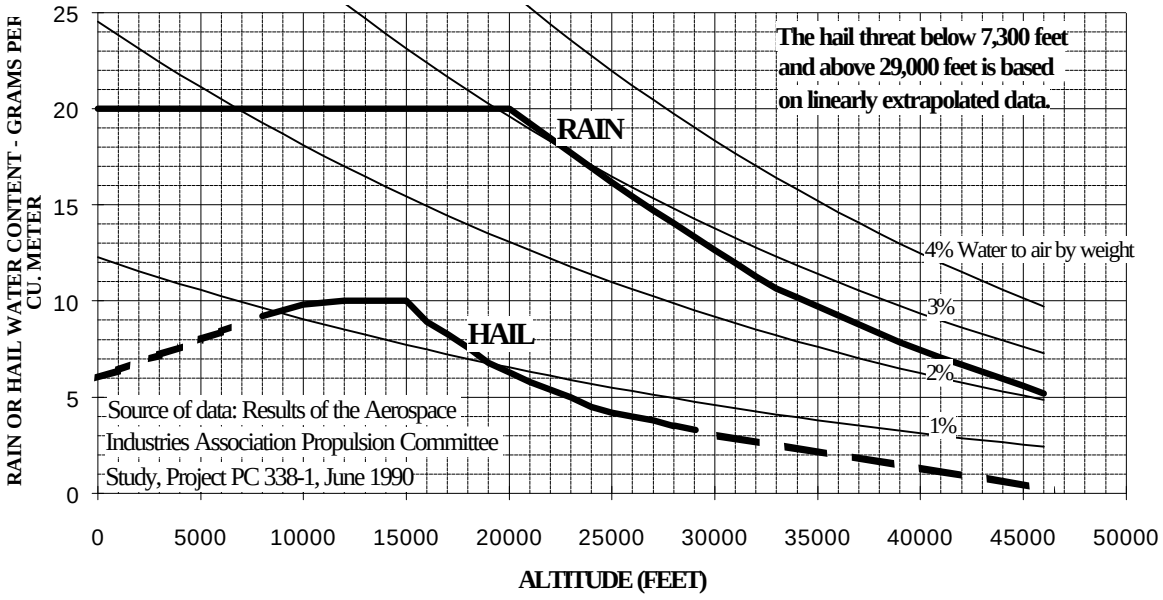

TABLE B1

CERTIFICATION STANDARD ATMOSPHERIC RAIN CONCENTRATIONS

Altitude (feet)	Rain Water Content (RWC) (grams water / meter^3 air)
0	20.0
20,000	20.0
26,300	15.2
32,700	10.8
39,300	7.7
46,000	5.2

RWC values at other altitudes may be determined by linear interpolation.

Note: Source of data - Results of the Aerospace Industries Association (AIA) Propulsion Committee Study, Project PC 338-1, June 1990.

TABLE B2

CERTIFICATION STANDARD ATMOSPHERIC HAIL CONCENTRATIONS

Altitude (feet)	Hail Water Content (HWC) (grams water / meter^3 air)
0	6.0
7,300	8.9
8,500	9.4
10,000	9.9
12,000	10.0
15,000	10.0
16,000	8.9
17,700	7.8
19,300	6.6
21,500	5.6
24,300	4.4
29,000	3.3
46,000	0.2

HWC values at other altitudes may be determined by linear interpolation. The hail threat below 7,300 feet and above 29,000 feet is based on linearly extrapolated data.

Note: Source of data - Results of the Aerospace Industries Association (AIA) Propulsion Committee (PC) Study, Project PC 338-1, June 1990.

TABLE B3

CERTIFICATION STANDARD ATMOSPHERIC RAIN DROPLET SIZE DISTRIBUTION

Rain Droplet Diameter (mm)	Contribution to total RWC (%)
0 - 0.49	0
0.50 - 0.99	2.25
1.00 - 1.49	8.75
1.50 - 1.99	16.25
2.00 - 2.49	19.00
2.50 - 2.99	17.75
3.00 - 3.49	13.50
3.50 - 3.99	9.50
4.00 - 4.49	6.00
4.50 - 4.99	3.00
5.00 - 5.49	2.00
5.50 - 5.99	1.25
6.00 - 6.49	0.50
6.50 - 7.00	0.25
TOTAL	100.00

Median diameter of rain droplets is 2.66 mm

Note: Source of data - Results of the Aerospace Industry Association (AIA) Propulsion Committee (PC) Study, Project PC 338-1, June 1990.

TABLE B4

CERTIFICATION STANDARD ATMOSPHERIC HAIL SIZE DISTRIBUTION

Hail Diameter (mm)	Contribution to total HWC (%)
0 - 4.9	0
5.0 - 9.9	17.00
10.0 - 14.9	25.00
15.0 - 19.9	22.50
20.0 - 24.9	16.00
25.0 - 29.9	9.75
30.0 - 34.9	4.75
35.0 - 39.9	2.50
40.0 - 44.9	1.50
45.0 - 49.9	0.75
50.0 - 55.0	0.25
TOTAL	100.00

Median diameter of hail is 16 mm

Note: Source of data - Results of the Aerospace Industries Association (AIA) Propulsion Committee (PC) Study, Project PC 338-1, June 1990.

Issued in Washington, DC on March 20, 1998.

/signed by

Jane F. Garvey
Administrator